TRACE: TRAC/RELAP Advanced Computational Engine
NRC Reactor Transient and LOCA Analysis

U. S. Nuclear Regulatory Commission, Washington D.C.

Vision and Long Term Direction

"To have the capability to perform T/H safety analysis in the future that allows for solutions to the full spectrum of important nuclear safety problems in an efficient and effective manner, taking complete advantage of state-of-the-art modeling, hardware, and software capabilities."

TRACE Project Goals

We must be able to reduce and consolidate personnel resources needed for solving any given problem and for maintaining code capability by developing and/or improving:
- ❖ Ease-of-use
- ❖ Speed
- ❖ Robustness
- ❖ Flexibility
- ❖ Maintainability/upgradeability

We must be able to accommodate the new challenges and demands for best-estimate T/H analysis coupled to other related capabilities:
- ❖ Accuracy
- ❖ Flexibility
- ❖ Maintainability/upgradeability
- ❖ Simplicity
- ❖ Expanded scope of capabilities
- ❖ Quality assurance

Historical Perspective

- ■ NRC relied on 4 T/Hcodes
  - ❖ PWR
    - ◆ RELAP5 ➫ SBLOCA and transients
    - ◆ TRAC-P ➫ LBLOCA
  - ❖ BWR
    - ◆ RAMONA ➫ 3D Kinetics and stability
    - ◆ TRAC-B ➫ LOCA's and transients

- ■ Over time the differences eroded but coding and input varied substantially

- ■ The suite was developed in the 70's and 80's and does not take advantage of modern technology
  - ❖ Old coding language and procedural style
  - ❖ Large container array
  - ❖ Archaic memory saving schemes (bit-packing)
- ■ Identified modeling deficiencies for the same phenomena

- ■ Architectural and modeling improvements required to ameliorate the limitations
  - ❖ NRC would have to expend 4 times the resources to continue making improvements to 4 separate tools

- ■ Continue to support old technology or invest in new technology?

- ■ Evolve from existing code base or "develop from scratch"?
  - ❖ Evolve!
    - ◆ Always have a running product
    - ◆ Takes advantage of current knowledge centers

Modeling Features

Able to Model All Reactor Designs

- ■ Modern BWR Channel Features
  - ❖ Partial length fuel rods
  - ❖ Square, cross, and round water rod geometries
  - ❖ Ray-traced radiation view factors
- ■ Extended Component Features
  - ❖ Additional valve and pump types
  - ❖ Active pressure boundary condition
  - ❖ Spherical heat structure geometry
  - ❖ New signal variable, control block, and trip types

- ■ Usability Enhancements
  - ❖ Command line argument support
  - ❖ Extended TRAC-B-style output
  - ❖ Improved code robustness
  - ❖ Platform-independent graphics and dump files

- ❖ Automatic sorting of control blocks, signal variables and trips
- ❖ Enhanced input checking
- ■ RELAP5, TRAC-P, and TRAC-BInput Deck Conversion
- ■ Additional Working Fluids (H$_2$O, D$_2$O, Air, N$_2$, He, Na, PbBi)
- ■ Generalized Support for Coarse-Grained Parallel and Coupled-Code Computations
- ■ SETS & Semi-Implicit Numerical Schemes
- ■ User-Defined Matrix Solvers
- ■ 1D&3D Kinetics (through PARCS coupling)
- ■ Advanced 1D & 3D Level Tracking
- ■ ASME Steam Tables
- ■ New Reflood Model
- ■ Improved Choked Flow Model
- ■ Enhanced User-Defined Material Tables

Modern Architecture

- ■ Decouple Computational Engine from Input Processor ➫

Previous TRACE Calculational and Data Flow

Flow Modified for Parallel Calculations

- ■ Parallelizable Flow Logic and Solution Scheme ➫

- ■ Object-Based Architecture ➫

Low-Level Object-Based Representation of Physical Property Evaluation Scheme

- ■ XML-Based Automated Generation of Source Code

- ■ Efficient List-Driven Internal Data Transfer Mechanism ➫

TRACE Support for 50.46 Break Size Redefinition

W 412 Standard Plant

- ■ Small Breaks
  - 2", 3", 4", 6" breaks
- ■ Transition breaks
  - SI, SI + 20%, SI – 20% , PSL
- ■ Emergency Diesel Generator (EDG) startup delay times of 10 seconds and 60 seconds

Conclusions

- ■ Increasing EDG start up time has small impact on PCT results
  - ❖ Results sensitivity to loop seal clearing is a known phenomena and is independent of delay time.
  - ❖ DEG mitigation not considered.

- ■ Increasing containment spray setpoint or relying on operator action is feasible for LOCA with break sizes up to SI (cold leg) and PSL (hot leg)
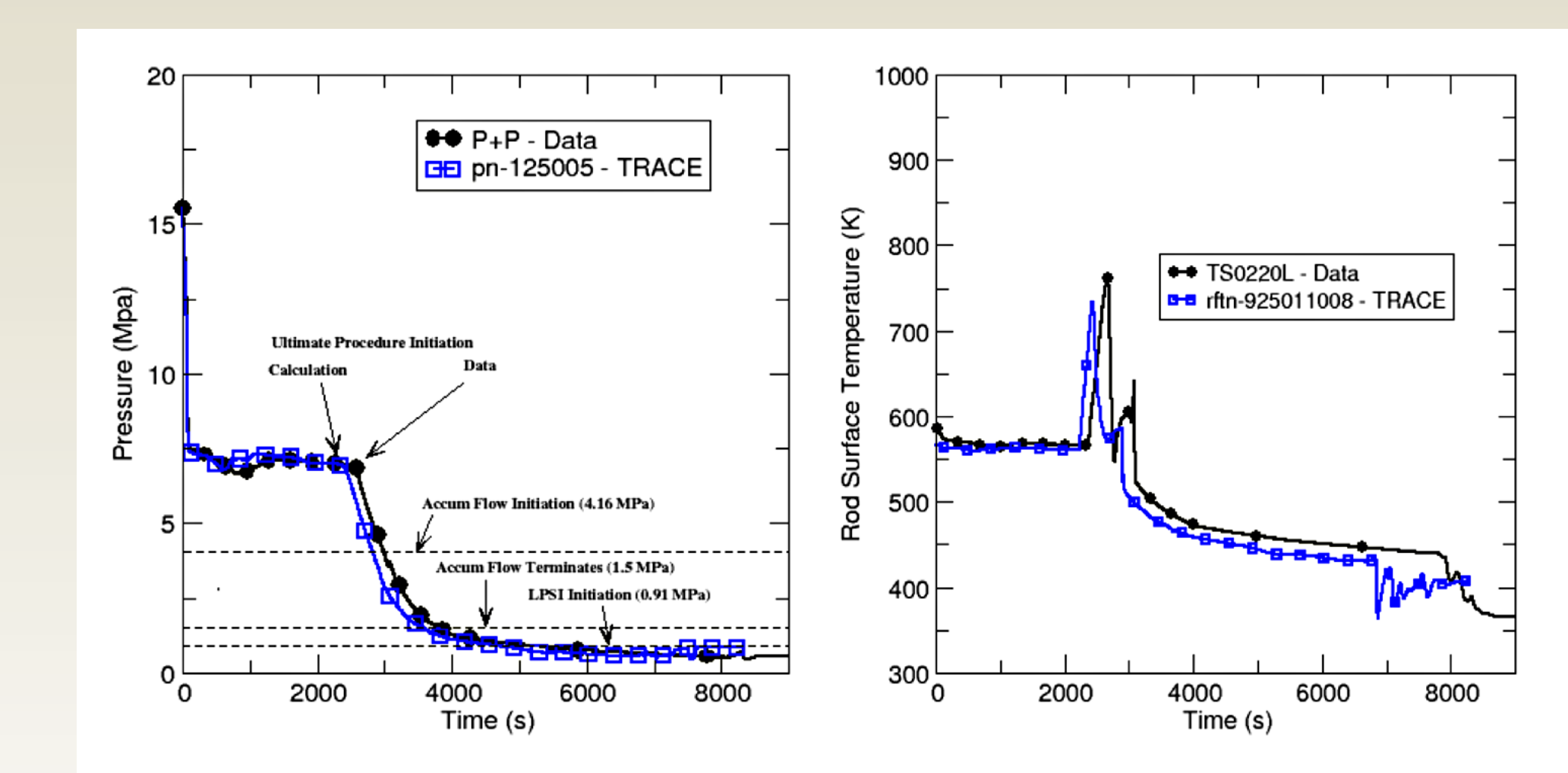 - ❖ Containment design specific

TRACE Assessment

- ■ The TRACE code is under development, but significant assessment has been performed with recent code versions.
- ■ Applicable integral assessment cases include:
  - ❖ ROSA SBLOCA IETs (6 tests)
  - ❖ BETHSY ISP-27

ROSA SB-CL-18 (ISP 26) Assessment
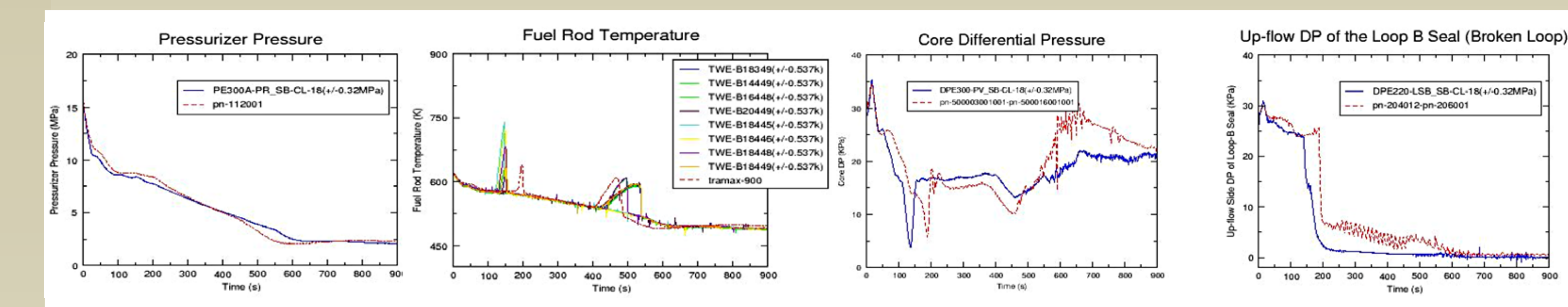
### Bethsy Test 9.1B (ISP-27) TRACE Simulation

TRACE Support for ESBWR Design Certification

ESBWR Passive Safety Systems

- ■ The ESBWR passive safety systems have strong coupling between the reactor and the containment.
- ■ ECCS System
  - ❖ Relies on depressurization like operating BWRs
  - ❖ Gravity driven cooling system (GDCS) to refill reactor system after blowdown.
- ■ Decay Heat Removal System
  - ❖ Large passive tube condensers (PCCS) to remove decay heat in long term cooling.

ESBWR Accident Phases
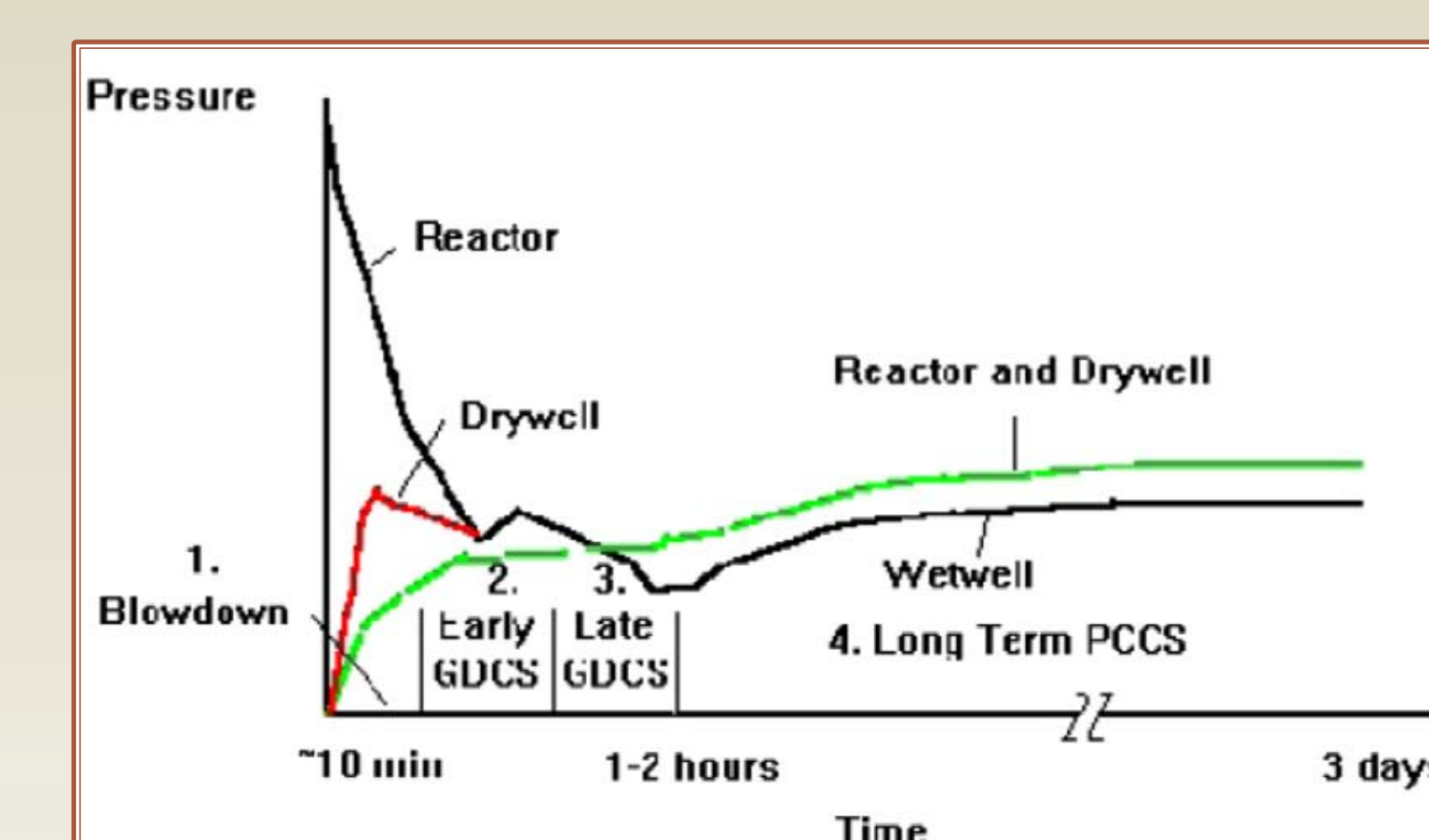
New TRACE Physical Models

Film condensation models appropriate for modeling tubes and containment walls have been added to TRACE.

TRACE Assessment for ESBWR

- ■ Separate Effects Test Assessment
  - ❖ Void fraction and level swell
  - ❖ Tube condensation
  - ❖ Flat plate condensation
- ■ Integral Test Assessment
  - ❖ FIST BWR full pressure blowdown
  - ❖ PUMA late GDCS to long term cooling
  - ❖ PANDA long term cooling

Current Status

- ■ New film condensation models have been added and are being assessed.
- ■ Integral test assessments are in progress.
- ■ Plant calculations are in progress.

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